Demand-Driven Business Cycles: Explaining Domestic and International Comovements

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Abstract

When capacity utilization is allowed to vary, standard equilibrium theory predicts that demand shocks can generate not only closed-economy business cycles that are previously thought explainable only by technology shocks, but also international business cycles that are more consistent with the data than what can be generated by technology shocks.

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1. Introduction

In real life, fickle consumers are often blamed for causing output fluctuations around its long-term trend sustainable by technology growth. Booms and recessions, for example, are usually thought by central bankers and business men as being driven by periods of consumer optimism and pessimism. In this paper, I show that random changes in consumer demand can indeed generate realistic features of the business cycle – for both closed and open economics – when the economy's production capacity can vary in response to changes in aggregate demand in an otherwise standard general equilibrium real business cycle model.

Other people have shown that shocks to consumption demand can be important for explaining the business cycle when there exist production externalities (most notably Baxter and King, 1991, Farmer and Guo, 1994, Wen, 1998, and Benhabib and Wen, 2000). I show here that even in the absence of externalities, demand shocks are capable of explaining many defining features of the US business cycle that are often thought explainable only by technology shocks, such as the positive comovement of domestic output, consumption and investment, as well as the relative volatility order among these variables.

More importantly, I show that demand shocks can help resolve many international business cycle puzzles documented recently in the open-economy literature, e.g., the high cross-country correlations for output and the low cross-country correlations for consumption; and the positive cross-country correlations for employment and investment. These international comovements are called *puzzles* or *anomalies* in the literature because they cannot be explained by standard open-economy models driven by technology shocks. In standard models, output, investment and employment are negatively correlated across countries, while consumption is strongly positively correlated across countries.[1] The existing literature suggests that market imperfections in one way or another are responsible for these anomalies. For example, Kehoe and Perri (2000) argue that incompleteness in the international credit markets may be responsible for these anomalies. Guo and Sturzenegger (1998) argue that externalities and increasing returns to scale can help resolve these anomalies.

[1] See Backus, Kehoe and Kydland (1992), Baxter and Crucini (1995), Stockman and Tesar (1995), and Kehoe and Perri (2000).

I show, however, that these international comovement anomalies are what standard economic theory predicts, once demand shocks are acknowledged as the primary source of fluctuations and once capacity utilization is allowed to vary in response to changes in aggregate demand. Imagine an increase in consumption demand in the home country. The increase raises demand for the world output (both domestic and foreign output). Output, employment and capacity utilization therefore increase both at home and abroad, resulting in their strong comovements across countries. Since the urge to consume (demand shocks) is country specific, consumption is less correlated across countries than is output.

Capacity utilization plays a key role in generating positive comovements in investment, as it alleviates the crowding out effect of consumption demand on investment by increasing the elasticity of output response to demand shocks, hence allowing for positive capital accumulation both at home and abroad to sustain the increase in the world demand. The observed international comovement patterns are thus fully consistent with a demand-driven business cycle theory.[2]

The propagation mechanism of the demand-driven channel of the business cycle can be further strengthened by allowing for habit formation on consumption – an essential element for explaining the equity premium puzzle. Habit formation renders changes in consumption demand highly persistent. Consequently, only *i.i.d.* demand shocks are required to generate highly persistent business cycles both domestically and internationally. This is in sharp contrast to the case of technology shocks, whose impact cannot be propagated effectively over time in standard models (e.g., see Cogley and Nason, 1995; and Wen, 1995).

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 explains in simple terms why demand shocks are essential for explaining international business cycles. Section 4 provides dynamic analysis, and section 5 concludes.

2. The Model

This is a simplified version of the two-country RBC model studied by Backus, Kehoe and Kydland (1992), with the additional features of variable capacity utilization and (possibly) rational habit formation on consumption. The theoretical

[2]The important role of capacity utilization in amplifying and transmitting the business cycle has been emphasized in the RBC literature by Greenwood et al. (1988), Burnside and Eichenbaum (1996), Wen (1998), King and Rebelo (2000), and Benhabib and Wen (2000).

world economy consists of two identical countries, each represented by a large number of identical consumers and an identical production technology. The countries produce the same good and have the same preferences. The labor input in each country, however, consists only of domestic labor, and consumption is subject to country-specific habit shocks.

In the home (h) and foreign (f) countries, the representative consumer maximizes the expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln\left(c_t^i - \rho c_{t-1}^i - \Delta_t^i\right) - a\frac{\left(n_t^i\right)^{1+\gamma}}{1+\gamma} \right\}, \quad \text{for } i = h, f, \tag{2.1}$$

where c is consumption of the produced good, n is labor supply, $\rho \in [0,1)$ is a habit persistence parameter, and Δ is a country specific random shock to the habit consumption level, which generates the urge to consume (Baxter and King, 1992).

Production of the single good takes place in each country according to the constant-returns-to-scale technology

$$y_t^i = \left(e_t^i k_t^i\right)^{\alpha} \left(n_t^i\right)^{1-\alpha}, \quad \text{for } i = h, f, \tag{2.2}$$

where $e \in [0,1]$ in the production function denotes capital utilization rate. To have an interior solution for e in the steady state, I follow Greenwood *et al.* by assuming that the capital stock depreciates faster if it is used more intensively:

$$\delta_t^i = \frac{1}{\theta}\left(e_t^i\right)^{\theta}, \quad \theta > 1, \quad \text{for } i = h, f; \tag{2.3}$$

where δ_t^i is the rate of depreciation. This imposes a convex cost structure on capital utilization. World output from the two processes, $y_t^h + y_t^f$, is allocated to consumption and fixed investment:

$$\sum_i \left[c_t^i + k_{t+1}^i - (1-\delta_t^i)k_t^i\right] = \sum_i \left(e_t^i k_t^i\right)^{\alpha} \left(n_t^i\right)^{(1-\alpha)}. \tag{2.4}$$

Next exports is $nx_t^i = y_t^i - \left[c_t^i + k_{t+1}^i - (1-\delta_t^i)k_t^i\right]$.

By exploiting the equivalence between competitive equilibria and Pareto optima, an equilibrium in this world economy can be computed as the solution to a planning problem of the following form:

$$\max \sum_i \left\{ E \sum_{t=0}^{\infty} \beta^t \left\{ \ln \left(c_t^i - \rho c_{t-1}^i - \Delta_t^i \right) - a \frac{(n_t^i)^{1+\gamma}}{1+\gamma} \right\} \right\} \tag{2.5}$$

subject to

$$\sum_i \left[c_t^i + k_{t+1}^i - \left(1 - \frac{1}{\theta} \left(e_t^i \right)^{\theta} \right) k_t^i \right] = \sum_i \left(e_t^i k_t^i \right)^{\alpha} \left(n_t^i \right)^{(1-\alpha)}, \tag{2.6}$$

for $i = h, f$. An equal weight is assumed in the objective function.

3. Static Analysis

To understand why demand shocks can help resolve the international comovement puzzles, I illustrate why technology shocks create these puzzles at the first place. Using a simpler version of my model (without loss of generality), assuming fixed capacity utilization and no habit formation, and denoting technology shocks as A^i for country i, then the first order conditions of the planning problem in the steady state are given by:

$$\frac{1}{c^i} = \lambda \tag{3.1}$$

$$a \left(n^i \right)^{\gamma} = (1-\alpha) A^i \lambda \left(k^i \right)^{\alpha} \left(n^i \right)^{-\alpha} \tag{3.2}$$

$$1 = \beta \left[\alpha A^i \left(k^i \right)^{\alpha-1} \left(n^i \right)^{1-\alpha} + 1 - \delta \right] \tag{3.3}$$

for $i = h, f$. These first order conditions imply the following cross-country ratios:

$$\frac{c^h}{c^f} = 1 \tag{3.4}$$

$$\frac{y^h}{y^f} = \frac{k^h}{k^f} = \left(\frac{A^h}{A^f} \right)^{\frac{1+\gamma}{\gamma(1-\alpha)}} \tag{3.5}$$

$$\frac{n^h}{n^f} = \left(\frac{A^h}{A^f} \right)^{\frac{1}{\gamma(1-\alpha)}}. \tag{3.6}$$

These cross-country ratios indicate a perfect cross-country correlation in consumption and imperfect cross-country correlations in other variables such as output, capital and labor (due to country specific technology shocks). In particular, under home-country technology shocks, output, capital and labor are negatively correlated across countries, because of international factor movement towards the country where the productivity is the highest. This implies that cross-country correlations for output, employment and investment will remain negative as long as country specific technology shocks are independent or not sufficiently positively correlated.

Thus puzzles arise: In the model, cross-country correlations are much higher for consumption than for output, while in the data the opposite is true; and in the model, cross-country correlations of employment and investment are negative, while in the data they are positive.

There is no puzzle, however, once the source of uncertainty is from the demand side rather than from technology. Under demand shocks, the above cross-country ratios become

$$\frac{c^h - \Delta^h}{c^f - \Delta^f} = 1, \tag{3.7}$$

$$\frac{y^h}{y^f} = \frac{k^h}{k^f} = \frac{n^h}{n^f} = 1. \tag{3.8}$$

These cross-country relationships imply that output, capital and labor are perfectly correlated across countries while consumption is imperfectly correlated across countries due to country specific demand shocks. Thus, cross-country correlations are higher for output than for consumption in the model, so are in the data; and cross-country correlations of employment and investment are positive, so are in the data.

The only issue left is the within-country comovement. For example, the correlation between domestic consumption and domestic investment can be negative due to the crowding out effect of demand shocks. Capacity utilization solves the crowding out problem, as it creates more elastic aggregate supply in response to changes in aggregate demand.

4. Dynamic Analysis

To study the model's dynamic responses to demand shocks, I solve the model's equilibrium decision rules by log-linearization around the steady state. I calibrate the model's parameters as follows: the time period t is a quarter, the capital income share $\alpha = 0.3$, the discount factor $\beta = 0.99$, the labor supply elasticity parameter $\gamma = 0$ (Hansen's (1988) indivisible labor),[3] the capacity elasticity parameter θ is chosen so that the steady state capital depreciation rate $\delta = 0.025$, and the steady state habit-demand to consumption ratio $\frac{\Delta}{c} = 0.1$.[4] The country specific demand shocks are modeled as log normal stationary $AR(1)$ processes:

$$\ln \Delta_t^i = \rho_\Delta^i \ln \Delta_{t-1}^i + \varepsilon_t^i, \quad \text{for} i = h, f, \tag{4.1}$$

where the persistence parameter ρ_Δ^i can be zero or positive, and where the innovations $\left(\varepsilon_t^h, \varepsilon_t^f\right)$ are *i.i.d.* white noises.

4.1. Comovement in Closed Economy

I first show in figure 1 the impulse responses of the home country to a domestic consumption demand shock when there is no trade.[5] The left window in figure 1 is the case with $AR(1)$ shocks and without habit formation $(\rho^h = 0.95, \rho_\Delta^h = 0)$; The right window in figure 1 is the case with *i.i.d.* shocks and habit formation $(\rho^h = 0, \rho_\Delta^h = 0.95)$.

Several remarkable features of figure 1 are worth mention. First of all, persistent demand shocks can generate positive comovement in output, consumption, investment and hours without habit formation. In particular, with respect to output, consumption is less volatile and investment is more volatile. Such a positive comovement and a relative volatility order among the three variables are two of the most robust and celebrated stylized business cycle facts that are thought in the literature explainable only by supply (technology) shocks in a standard model.[6]

Secondly, when habit formation is allowed for, the model has a rich endogenous propagation mechanism that can transform the impact of *i.i.d.* demand shocks into highly persistent movement in output, investment and employment (see the right window). This happens because habit formation renders shocks to consumption

[3] $\gamma > 0$ is required in the case of technology shocks in order to avoid singularity.

[4] The model's predictions are not sensitive to this ratio.

[5] The impulse responses of a closed economy can be obtained from the two-country model by simulating the model under an equal and perfectly correlated impulse of consumption demand in both countries (so that no trade takes place).

[6] If both persistent demand shocks and habit formation are allowed, consumption can be even smoothed further.

demand *endogenously* persistent. This is in sharp contrast to the case of technology shocks whose impact can last only as long as the shocks themselves in standard models (e.g., see Cogley and Nason, 1995; and Wen, 1996). The combination of $AR(1)$ demand shocks and habit formation can generate even more volatile investment. This is shown in figure 2.

The model has other virtues. Rotemberg and Woodford (1996) highlight a characteristic of economic fluctuations that is difficult for standard RBC models to explain. They show that, in US data, forecastable changes in output, hours, investment and consumption are positively correlated, whereas standard RBC models predict the opposite. With capacity utilization and habit formation incorporated into an otherwise standard RBC model, the forecastable changes in these four variables become positively correlated. Figure 3 shows that output, consumption, investment and employment comove in the same direction in the transition to the steady state after a decrease in the capital stock.[7] In particular, hours and capacity utilization both increase when capital stock lies below its steady state, generating more output available for both investment (capital accumulation) and consumption (although the magnitude of consumption is relatively very small compared to output and investment). Hence, along the transition paths, these variables comove together. In addition, consumption is less volatile and investment is more volatile than output along the transition path – another stylized fact emphasized by Rotemberg and Woodford (1996) as evidence against standard RBC models.

4.2. Comovement in Open Economy

In open economy settings, Backus, Kehoe and Kydland (1992), Baxter and Crucini (1995), Stockman and Tesar (1995), and Kehoe and Perri (2000) find two major discrepancies between standard general equilibrium models and the data. In the open economy models, cross-country correlations are much higher for consumption than for output, while in the data the opposite is true; and cross-country correlations of employment and investment are negative, while in the data they are positive. Since these two discrepancies are robust to changes in both parame-

[7] It is shown by Rotemberg and Woodford (1996) that the forecastable (permanent) movement of a model can be captured by the transitional dynamics of the model with capital starting off its steady state. Figure 2 shows the transitional dynamics when capital starts one percent below its steady state.

ter values and the model structure, Backus, Kehoe and Kydland (1992) call them *anomalies*.

One way to deal with these anomalies was suggested by Stockman and Tesar (1995), who consider an economy with nontraded goods and both technology and demand shocks. The introduction of nontradable consumption goods reduces the cross-country correlation of aggregate consumption because agents do not have incentives to trade claims on the output of the nontraded goods sector. Alternatively, it has been shown that incomplete asset or commodity markets may help resolve these anomalies. For example Baxter and Crucini examine an economy in which agents trade a single risk-free bond, Kehoe and Perri (2000) examine an economy in which international loans are imperfectly enforceable, and Guo and Sturzenegger (1998) examine an economy in which there are no markets for claims contingent on 'sunspot' states.

As I pointed out earlier, the observed international comovement pattern is what standard economic theory predicts. It is a classical "Keynesian" story of aggregate demand.

Consider an increase in consumption demand in the home country. Such increase raises demand for both domestic and foreign output. Output, employment and capacity utilization therefore all increase both at home and abroad in response to the higher world demand. In the mean time, since variable capacity utilization reduces the crowding-out effect of consumption on investment, investment in both home and foreign countries also go up so that both countries can maintain necessary amount of capital stocks to sustain the persistent increases in world demand.[8] Consequently, we see international comovement in output, investment and employment. Since the urge to consume (demand shocks) are country specific, consumption is less correlated across countries than is output.

Figure 4 shows the impulse responses of the home country (first column) and the foreign country (second column) to an *i.i.d.* demand shock in the home country. It is seen there that output, investment and employment are highly persistent in both countries and are perfectly synchronized across countries, while consumption is imperfectly correlated across countries.

When both countries are subject to demand shocks, simulations are required to characterize the dynamics of the model. Table 1 reports means and standard deviations of sample moments computed from 500 simulations of the world economy,

[8] The increases in world demand are persistent either due to persistent demand shocks or due to habit formation on consumption demand.

each with a length of 100 periods. Three versions of the models are simulated, one corresponding to *i.i.d* shocks with habit formation, another corresponding to $AR(1)$ shocks without habit formation, and another corresponding to $AR(1)$ shocks with habit formation. Since I am interested only in qualitative results regarding international comovements, in all cases the cross correlations of the country specific demand innovations, $cor(\varepsilon^h, \varepsilon^f)$, are set to zero and calibration is not used.

The table shows that in an open economy setting, the relative volatility of consumption to output exceeds one with large standard errors, implying that it can be either less than one or greater than one depending on a particular realization of the shocks. Investment, on the other hand, is always more volatile than output (although it is less than the data suggests). The ratio of net export to output is always negatively correlated with output, which is a robust empirical regularity documented by the open-economy literature (e.g., see Backus, Kehoe and Kydland, 1992, and Kehoe and Perri, 2000). Standard models driven by technology shocks predict this ratio to be procyclical, rather than counter cyclical. The international comovements are also consistent qualitatively with the data, in that output, investment and employment are strongly correlated across countries and that consumption is less correlated across countries than is output.

The perfect cross-country correlations of output, employment and investment can be reduced if nonseparable period utility functions are used. When consumption and leisure are nonseparable, consumption demand shocks also affect labor supply, hence reducing cross-country correlations for output, employment and investment. However, output will remain more strongly correlated across countries than consumption. On the other hand, the cross-country correlations for consumption can be increased further if the cross-country correlations of the innovations, $cor(\varepsilon^h, \varepsilon^f)$, are allowed to be positive.[9]

[9] A rough calibration by Guo and Sturzenegger (1998) shows that this correlation is about 0.45.

Table 1. Open-Economy Business Cycle Statistics (std. errors in parentheses)

	i.i.d. with habit	$AR(1)$ without habit	$AR(1)$ with habit
Relative volatility to GDP			
σ_c/σ_y	1.35 (0.37)	1.23 (0.35)	1.20 (0.37)
σ_i/σ_y	1.46 (0.07)	1.46 (0.07)	2.44 (0.38)
Domestic Comovement			
$\rho(c,y)$	0.63 (0.21)	0.68 (0.19)	0.62 (0.24)
$\rho(i,y)$	0.98 (0.01)	0.98 (0.01)	0.81 (0.03)
$\rho(n,y)$	0.99 (0.0)	1.0 (0.0)	0.99 (0.0)
$\rho(nx/y,y)$	-0.77 (0.15)	-0.81 (0.13)	-0.83 (0.13)
International Comovement			
$\rho(y^h,y^f)$	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
$\rho(c^h,c^f)$	-0.1 (0.34)	0.01 (0.34)	0.05 (0.43)
$\rho(i^h,i^f)$	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
$\rho(n^h,n^f)$	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)

5. Conclusion

I have shown that many defining features of the business cycle can be explained by demand shocks alone. In particular, demand shocks predict that: 1) Domestic output, consumption, investment and hours comove together. 2). The forecastable movements in output, consumption, investment and hours comove together. 3) Output, investment and hours are positively correlated with their respective counter parts across countries, with stronger cross-country correlation for output than is for consumption. 4) Net export to output ratio is negatively correlated with output. These domestic and international comovement patterns are well documented in the business cycle literature.

The key element for the success of my model is capacity utilization. Variable capacity utilization mitigates the crowding out effect, rendering demand shocks fully expansionary both domestically and internationally. Habit formation, on the other hand, strengthens the demand channel of business cycle propagation by making *i.i.d.* shocks to consumption demand *endogenously* persistent.

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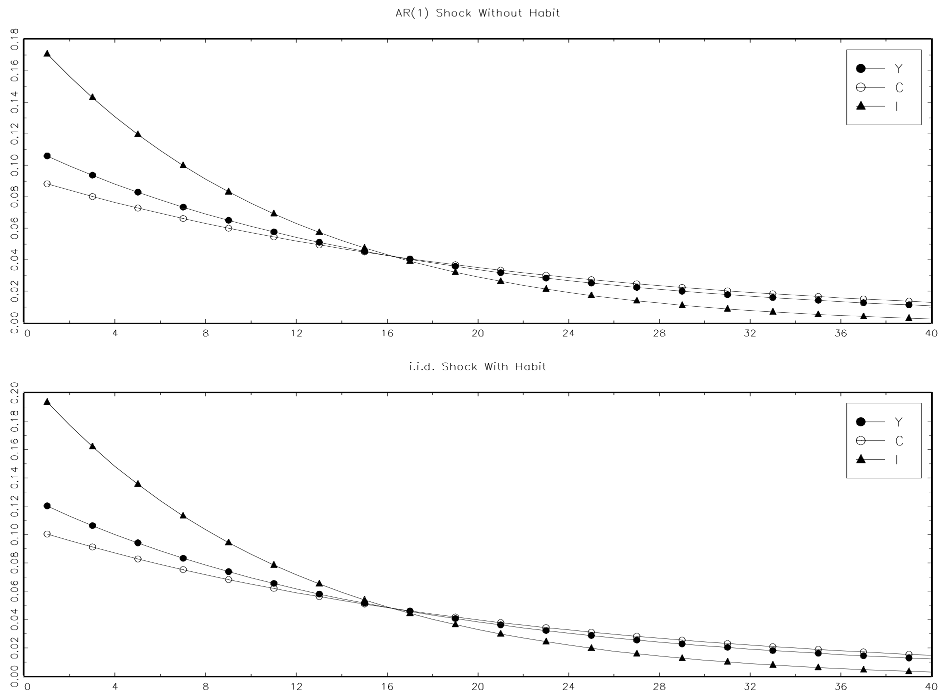

Fig. 1. Impulse Responses in Closed Economy.

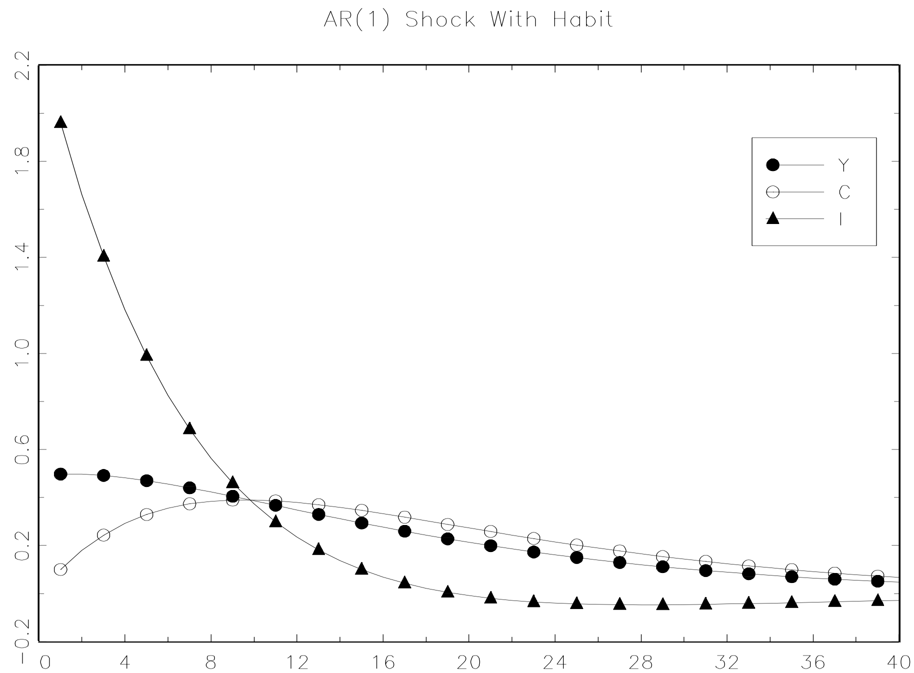

Fig.2. Impulse Responses in Closed Economy.

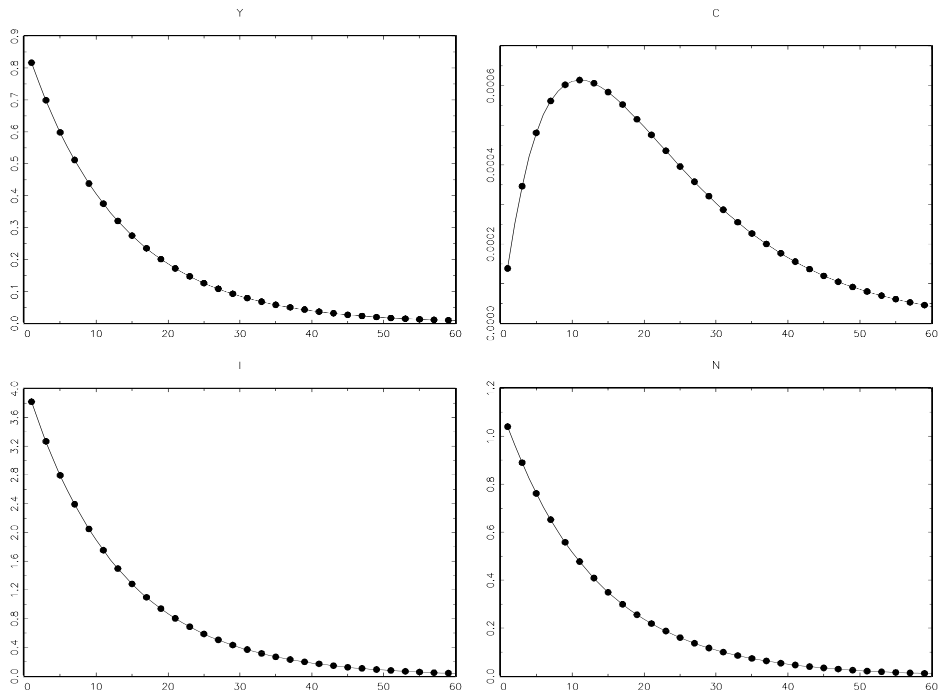

Fig. 3. Forecastable Movements in Output, Consumption, Investment and Employment.

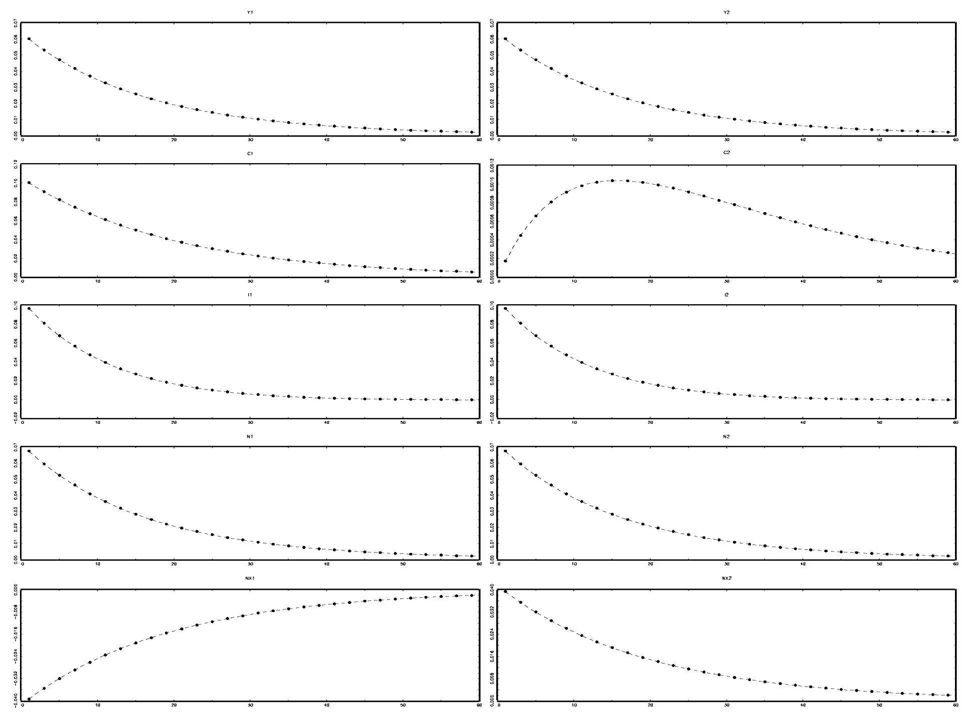

Fig. 4. International Comovements – Impulse Responses to a Home Country i.i.d. Shock. First Column = Home Country; Second Column = Foreign Country. Order of Variables from Top = Output, Consumption, Investment, Hours and Net Export.